(IJITR) INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND RESEARCH
Volume No.4, Issue No.6, October – November 2016, 5072-5075.

A Novel Contrast Enhancement Algorithm Using HSV Color Space

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Abstract: **The goal of contrast enhancement is to provide a more appealing image. Histogram equalization (HE) is a nonlinear technique for adjusting the contrast of an image using its histogram. Conventional contrast enhancement techniques often fail to produce satisfactory results for low-contrast images and cannot be automatically applied to different images because processing parameters must be specified manually to produce satisfactory results for a given image. This paper proposes a contrast enhancement technique to enhance color images captured under poor illumination and varying environmental conditions. First images are converted from RGB to HSV color space where enhancement is achieved and reconverted to the RGB. Class Limited Adaptive Histogram Equalization (CLAHE) is used to enhance the luminance component (V). Discrete Wavelet Transform (DWT) is applied to the Saturation(S) components, and the decomposed approximation coefficients are modified by a mapping function derived from scaling triangle transform. Inverse Wavelet transform is used to obtain the enhanced S component. The image is then converted back to the RGB color space. The parameters Peak-signal-to-noise ratio (PSNR), Absolute Mean Brightness Error (AMBE) and Mean squared error (MSE) were used for performance evaluation. The algorithm implemented in MATLAB was tested and compared with outputs of Histogram Equalization and CLAHE enhancement techniques. The result shows that the new algorithm gave the best performance among the others.**

Key words: **Class Limited Adaptive Histogram Equalization (CLAHE); Discrete Wavelet Transform (DWT);**

I. INTRODUCTION

Contrast is the difference in luminance or intensity level between objects or regions in an image. If the contrast is too low, all pixels are a mid-shade of gray making the objects to fade into each other. Hence, low contrast causes loss of information in some areas in the image, while good contrast makes objects or scenes depicted in an image distinguishable and visually interpretable for human and machine analysis. Many algorithms for achieving contrast enhancement have been developed. Among them is histogram equalization technique that is attractive due to its simplicity.

The histogram of an image represents the relative frequency of occurrence of grey levels within an image. Histogram modeling techniques are used to modify the gray scale range and contrast values of an image such that its intensity histogram fits a desired shape. Histogram Equalization is used to modify an input image s intensity histogram in order to obtain an output image with a uniformly distributed histogram. The resultant effect will be that the output image will have a perception that overall contrast is optimal (thus the image is enhanced). The process of histogram equalization involves the use of a transfer function which reassigns the brightness values of display pixels based on the input image histogram. The process does not affect individual pixels brightness order (that is they remain brighter or darker than other pixels) but only modify/shift the brightness values so that an equal number of pixels have each possible brightness value.

An adaptation of histogram equalization is the contrast limited adaptive histogram equalization (CLAHE). CLAHE divides input image into a number of equal size blocks and then performs contrast limited histogram equalization on each block. The contrast limiting is done by clipping the histogram before histogram Equalisation.

Earlier works have also shown that the performance of HSV color space is good in color improvement. Hue preservation methods keep the Hue constant to avoid the problem of color shifting, while either only the Luminance (V) component or both Luminance (V) and Saturation(S) components are modified to make the image soft and vivid. Compared with other models such as CIE LUV color space and CIE Lab color space, it is easier to control the Hue component and still avoid color shifting in the HSV color space. This work proposes a Hue preserving algorithm, which uses a derived mapping function to modify the Saturation components, and CLAHE for Luminance components.

II. PROPOSED METHOD

First images are converted from RGB to HSV color space where enhancement is achieved and reconverted to the RGB. Class Limited Adaptive Histogram Equalization (CLAHE) is used to enhance the luminance component (V). Discrete

Wavelet Transform (DWT) is applied to the Saturation(S) components, and the decomposed approximation coefficients are modified by a mapping function derived from scaling triangle transform. Inverse Wavelet transform is used to obtain the enhanced S component. The image is then converted back to the RGB color space. The complete algorithm for the image enhancement method is presented in the flow process below and the flowchart in Figure 1.

Algorithm

1) Load a color image
2) Convert from RGB to HSV color space
3) Enhance luminance (V) component using CLAHE.
4) Apply Discrete Wavelet Transform (DWT) to saturation (S) component
5) Use a derived mapping function to modify approximate coefficients from (4).
5) Reconstruct S using Inverse Discrete Wavelet transform.
7) Combine H, new S component, and V components to get the enhanced HSV image
8) Convert from HSV to RGB color space.

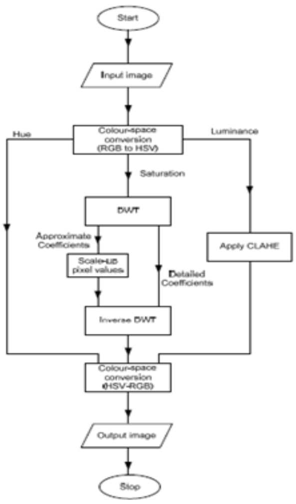

Fig.1 Flow chart of Image Enhancement algorithm

A. *Color Space Conversion*

Conversion from RGB to HSV color space is achieved through equations (1) to (5).

$R' = R/255;\ G' = G/255;\ B' = B/255 \qquad (1)$

If,

$C_{MAX} = \max(R', G', B');$

AND $\text{Ø} = C_{MAX} - C_{MIN} \qquad (2)$

Then

$$H = \begin{cases} 60^0 \times \left(\frac{G'-B'}{\Delta} mod6\right), & C_{max} = R' \\ 60^0 \times \left(\frac{B'-R'}{\Delta} + 2\right), & C_{max} = G' \\ 60^0 \times \left(\frac{R'-G'}{\Delta} + 4\right), & C_{max} = B' \end{cases} \qquad (3)$$

$$S = \begin{cases} 0 & , \Delta = 0 \\ \frac{\Delta}{C_{max}} & , \Delta <> 0 \end{cases} \qquad (4)$$

And $V = C_{max}$ (5)

B. *Discrete Wavelet Transform*

It is shown that discrete wavelet transform (discrete in scale and shift, and continuous in time) is successfully implemented as analog filter bank in biomedical signal processing for design of low-power pacemakers and also in ultra-wideband (UWB) wireless communications.

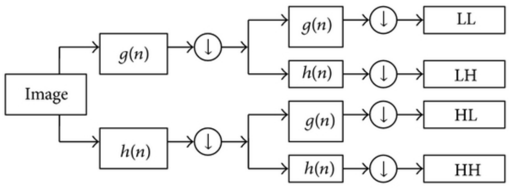

Fig.2 2D 4 Band Filter bank DWT

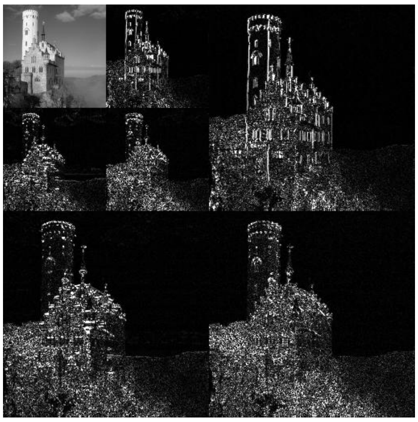

Fig. 3 2D DWT in JPEG2000

Fig. shows the example of the 2D discrete wavelet transform that is used in JPEG2000. The original image is high-pass filtered, yielding the three large images, each describing local changes in brightness (details) in the original image. It is then low-pass filtered and downscaled, yielding an approximation image; this image is high-pass filtered to produce the three smaller detail images, and low-pass filtered to produce the final approximation image in the upper-left.

C. *Contrast Enhancement of Saturation Component*

Discrete Wavelet Transform was applied to the Saturation Component of the image. An enhancement algorithm (derived mapping function) was applied to the approximate component of the wavelet decomposition. Wavelet transform of Image I(x,y) produces s(x,y), which is further decomposed into approximate A and detailed components D as shown in equation (6)

$$S(x,y) = \sum_{j=0}^{n-1} A_j \emptyset_{jn}(x,y) + \sum_{j=0}^{n-1}\sum_{k=0}^{n} D_{jk}\varphi_{jk}(x,y) \quad (6)$$

Where Ø is the scale is function and Ø is the wavelet function.A_J ' are approximate coefficients and D_{jk}' are detail coefficients.

Mapping function for modification of the Saturation component is derived from two equilateral triangles, where one is a scaled version of the other as shown in Figure 3. The minimum value of the decomposed signal is mapped to the base of the 'smaller' triangle, while the maximum value ismapped to the tip of the same triangle. Each value is up-scaledto a new one, represented by an equivalent point on the 'bigger' triangle using the algorithm shown in (7). New minimum and maximum values for the pixels were fixed through a search method and the optimum value that produced the best result selected.

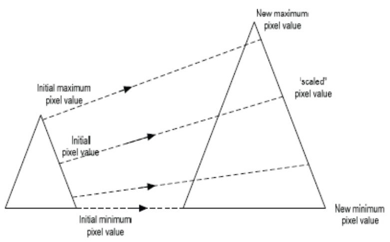

Fig.4 Scale-up triangle model

$$newmin = (oldmin \times 2.5289);$$
$$newmax = (oldmax \times 0.9)$$
$$For i = 1\, to H; and j = 1\, to W$$

$$newA(i,j) = newmax - \frac{(newmax - oldA(i,j)) \times (newmax - newmin)}{oldmax - oldmin} \quad (7)$$

Where i and j represents the row and column respectively, which stands for the location of a particular approximate component of a pixel. The enhanced Saturation (S) value is obtained through inverse wavelet transform of the new approximate and original decomposition coefficients.

$$S'(x,y) = \sum_{j=0}^{n-1} A'_j \emptyset_{jn}(x,y) + \sum_{j=0}^{n-1}\sum_{k=0}^{n} D_{jk}\varphi_{jk}(x,y) \quad (8)$$

D. Contrast Enhancement of Luminance Component

CLAHE was adopted for the enhancement of the V component in the HSV color space. The V component image is divided into 8×8 tiles. The clip-limit used is 0.01. Uniform distribution is used as the histogram shape for the image tiles. The expression of modified gray levels for standard CLAHE method with Uniform Distribution can be given as

$$g = [g_{max} - g_{min}] * P(f) + g_{min} \quad (9)$$

Where g_{max}= maximum pixel value

g_{min}= minimum pixel value

g= computed pixel value

$P(f) = cummulative\ probability\ distribution$

E. Conversion to RGB

Inverse conversion to RGB after enhancement is achieved through the processes described by the equations (10) to (16).

$$h_i = \left(\frac{H}{60}\right) mod6, \quad (10)$$

$$f = \frac{H}{60} - h_i, \quad (11)$$

$$p = v \times (1 - s), \quad (12)$$

$$q = v \times (1 - f \times s), \quad (13)$$

And $t = v \times (1 - (1 - f) \times s)$ (14)

For each color vector (r, g, b),

$$(r,g,b) = \begin{cases} (v,t,p), & if h_i = 0 \\ (q,v,p) & if h_i = 1 \\ (p,v,t) & if h_i = 2 \\ (p,q,v), & if h_i = 3 \\ (t,p,q), & if h_i = 4 \\ (v,p,q), & if h_i = 5 \end{cases} \quad (15)$$

he values of R, G, B are

$$R = r \times 256, \quad G = g \times 256, \quad and\ B = b \times 2 \quad (16)$$

III. EXPERIMENTAL RESULTS

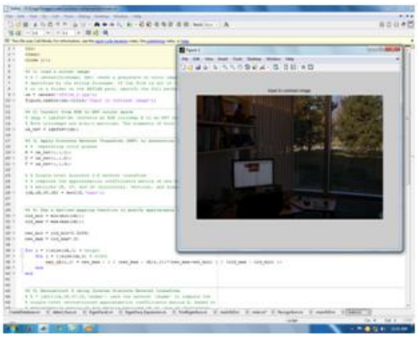

Fig. 5 Low contrast image

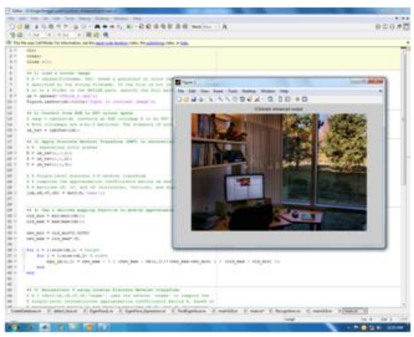

Fig. 6 Contrast Enhanced image

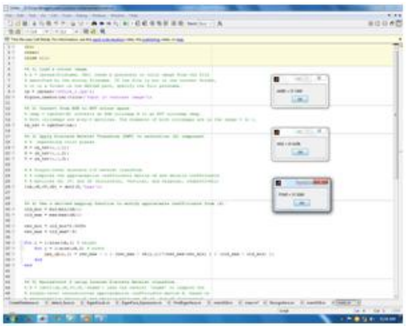

Fig.7 performance metrics

IV. CONCLUSION

In this Paper, an algorithm where the color image enhancement is achieved in the frequency domain is presented. The Hue component is preserved (unchanged), luminance modified using CLAHE, while Saturation components were up-scaled using a derived mapping function on the approximate components of its discrete wavelet transform. The method performed best when compared with outputs of HE and CLAHE methods, through preservation of image quality and increased dynamic range of image brightness.

V. REFERENCES

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